

**SMART CARD THAT CAN BE CONFIGURED FOR
DEBUGGING AND SOFTWARE DEVELOPMENT
USING SECONDARY COMMUNICATION PORT**

Field of the Invention

This invention relates to the field of smart cards, and more particularly, this invention relates to debugging and software development of a dual-mode smart card using a secondary communication port for debugging code or extracting variable or data from registers.

Background of the Invention

Smart cards are plastic cards having an embedded Integrated Circuit (IC). That IC may be a logic circuit with its associated memories or a microcontroller with its associated memories and software, or a microcontroller with its associated memories and software coupled to a custom circuit block or interface.

To use the computing power of the IC, a smart card makes use of a full set of packaging technologies. For example, the die size varies from 1mm^2 to 30mm^2 , but is limited because of the mechanical limitations imposed by the plastic construction of the smart card. The IC is attached to a lead frame and wire-bonding techniques are used to connect the IC pads to the lead frame contacts. Potting or other strengthening methods can be used to protect the IC against chemical and mechanical stresses during manufacturing and are a part of everyday usage of a smart card. Eight contacts are

located on one side of the card. The smart card performs transactions with a smart card reader using a serial protocol. The mechanical and electrical specifications for a smart card are published by the
5 International Standard Organization (ISO) as ISO7816-X standards, which have allowed the simple and massproduced magnetic stripe cards to evolve toward the smart card. This natural evaluation has allowed smart cards, depending of the IC complexity, of course, to
10 perform pre-paid accounting, cryptographic scheme, personal authentication using a PIN code, biometrics, and java scripts, for example.

ISO documents ISO 7816-1 Physical Characteristics, ISO 7816-2 Dimensions and Locations of
15 the contacts, ISO 7816-3 Electronic signals and transmission protocols, ISO 7816-4 Interindustry Commands for Interchange, and ISO 7816-10 Electronic signals and answer to reset for synchronous cards are incorporated herein by reference.

20 In operation, smart card readers are recognized by the reader infrastructure or a host computer prior to performing any transaction involving a smart card. The infrastructure runs an application involving the smart card. The half duplex protocol
25 between the smart card and the smart card reader, in which either the smart card sends information to the smart card reader or vice versa, cannot start until a smart card is in place and detected by the smart card reader. The infrastructure manages authentication or
30 transactions for pre-paid cards in public telephony, for Bankcards in Point-of-Sale (POS) terminals and Automatic Teller Machines (ATM), for Pay TV providers in set top boxes, and for wireless telecom operators in Subscriber Identification Modules (SIM) used in Global
35 System for Mobile (GSM) terminals. Except for SIM

cards, all other smart card reader applications use a physical sensor to detect the smart card. This sensor tells the smart card reader when a smart card is in place, i.e., when the smart card lead frame contacts
5 mate with the smart card reader contacts.

When the smart card reader has established that a smart card is in place, a power-up sequence begins. After this power-up sequence has finished, the smart card reader typically provides a clock to the
10 smart card and releases a reset signal. The smart card then executes its stored Operating System (OS). The SIM card, on the other hand, is in place only once with the power-off and used constantly subsequent to its positioning.

15 The first application for smart card technology was the public telephone system. The smart card die size was typically less than 1mm^2 , and only memories and logic circuits were integrated in the IC. The smart card reader used all eight contacts to
20 interface properly with the different smart card generations. When the smart card was inserted in the payphone, the telephone infrastructure authenticated the smart card and the telephone removed "units" from the smart card.

25 The banking industry subsequently adopted smart cards. The die size was about 10mm^2 , and a microcontroller and its associated memories and software were integrated in the IC. The smart card reader used up to six contacts to interface properly
30 with the different smart card generations. When a smart card was inserted in the ATM or the POS (point-of-sale), the smart card user was authenticated with a PIN code. The smart card could store different items, such as the balance of cash received from an ATM on a
35 per week basis or details of purchases since a last

closing date. Based on this information, authorization could be issued on the spot once the PIN had authenticated the debtor. This was accomplished without telephone calls to the bank.

5 Another application for smart cards has been developed by GSM manufacturers. The die size in a SIM is about 30mm², and a microcontroller and its associated memories and software are integrated in the IC. The SIM reader uses five contacts to interface properly
10 with the smart card. The more sophisticated smart card applications are performed in GSM using Java applets.

 A new market for the smart card has emerged with the growth of the internet accessed from a personal computer. Secure message, Public Key
15 Infrastructure, Authentication and Electronic Payment are new smart card areas of interest. The smart card acts as an e-commerce facilitator. One advantage of a smart card compared to other solutions is the smart card PIN and cryptographic keys can be stored in its
20 memory and never leave the smart card to be communicated in any transaction.

 Presently, a smart card is inserted into a smart card reader connected to a host computer. Two protocols are involved in supporting transactions
25 between the smart card and host computer. The first protocol complies with the ISO-7816-3, which provides detailed requirements for the serial interface between smart card and smart card reader. The reader is connected to the computer via a serial port, a parallel
30 port, or the Universal Serial Bus (USB), using a second protocol. The smart card reader contains electronic circuits and embedded software that enable communication between the smart card using the first protocol and the host computer using the second

protocol. The host computer is loaded with any appropriate drivers to support the smart card reader.

Many countries have begun to use the smart card in the PC environment. The die size used in these applications ranges from 5mm² to 30mm², and the microcontroller and its associated memories and software are integrated in the IC typically with a cryptocontroller. Sometimes, a bio-sensor is integrated. The smart card reader uses at least five contacts to interface properly with the smart card in these applications.

Since the late 1990's, the universal serial bus (USB) has become firmly established and has gained wide acceptance in the PC marketplace. The USB was developed in response to a need for a standard interface that extends the concept of "plug and play" to devices external to a PC. It has enabled users to install and remove external peripheral devices without opening the PC case or removing power from the PC. The USB provides a low-cost, high performance, half-duplex serial interface that is easy to use and readily expandable.

USB uses four wires. The power supply is carried with two wires (VBus and ground), and data is carried with the other two wires (D+, D-). The latest version of the USB is currently defined by the Universal Serial Bus Specification Revision 2.0, written and controlled by USB Implementers Forum, Inc., a non-profit corporation founded by the group of companies that developed the USB Specification.

In particular, Chapter 5 USB Data Flow Model, Chapter 7 Electrical, Chapter 8 Protocol Layer and Chapter 9 USB Device Framework of Universal Serial Bus Specification are incorporated herein by reference. The increasingly widespread use of the USB has led

smart card reader manufacturers to develop USB interfaces for connection of their products to host computers to complement the existing serial and parallel interfaces.

5 Although some industries, e.g., banking, have used smart card technology for years, internet users have not taken advantage of smart card technology. Although most internet transactions originate from a PC, and despite some efforts from PC manufacturers, the
10 PC industry has failed to install on each PC a cost effective smart card reader that meets the specific needs of web related applications. To aid this process, "dual mode" smart cards have been developed.

 U.S. Patent No. 6,439,464 to Fruhauf et al.,
15 the disclosure which is hereby incorporated by reference in its entirety, discloses a dual mode smart card IC that operates in a first mode, such as an ISO mode in accordance with International Standards Organization 7816 (ISO) protocol, and a USB mode in
20 accordance with the universal serial bus (USB) protocol. This dual-mode IC is implemented as a smart card and includes a microprocessor, switching block, and external interface.

 A voltage supply pad, a ground or reference
25 voltage pad, a first set of pads for the first mode, and a second set of pads for the USB mode, form the interface. The first set of pads preferably includes a reset pad, clock pad and an input/output pad in accordance with the ISO 7816 protocol. The second set
30 of pads preferably includes a D+ pad and a D- pad in accordance with the USB protocol. The IC further includes a mode configuration circuit comprising a USB mode detector connected to at least one of the D+ and D- pads. A pull-up resistor preferably connects to one
35 of the D+ and D- pads and a USB voltage detector

preferably connects to the voltage supply pad. A latching circuit is connected between the switching block and USB detector, and a control register is connected to the latching circuit for storing a low configuration indicator.

When the dual-mode IC is configured in the USB mode, the first set of pads is disabled based on verification of the USB voltage. When the dual-mode IC is configured in the ISO mode, the second set of pads is disabled after the USB-mode condition is not detected.

The smart cards that are dual mode smart cards as described above and that support ISO 7816 or the USB standard are currently configured in user mode with only one of these communication ports. When the USB port is enabled, the ISO 7816 port is disabled. On the other hand, when the ISO 7816 port is enabled, the USB port is disabled. A primary reason for this functionality is security. It is not desirable to allow potential hackers or software pirates any opportunity to extract from the smart card any information and data regarding the embedded code. In the block and/or lock of the operating mode for the USB or the ISO 7816 mode, the hardware is automatically switched to the corresponding mode after mode detection. Although this provides security when the card is in operation during debugging, however, or in the development of the embedded code, it would be advantageous to use a secondary communication port to download debugging codes or extract data regarding variable or registers. This is not possible with a current ISO or USB smart card.

Some prior art systems have used a Joint Test Action Group (JTAG) interface port. This solution requires additional hardware support, which is costly.

A more feasible solution would use predominantly software without the additional hardware, such as the JTAG interface port.

Summary of the Invention

5 It is therefore an object of the present invention to provide a system and method to allow debugging and software development of embedded code or data extraction regarding variables or registers with a current ISO or non-ISO, such as a USB smart card.

10 The present invention advantageously uses an inactive port, for example, the secondary communications port, for debugging code or extracting variable or registers information in a dual mode smart card. Thus, a debugging port is provided for a USB
15 smart card operating in the USB mode as user mode and provides a debugging port for an ISO/USB smart card operating in ISO mode as the user mode. The security of the smart card is guaranteed as the debug port is accessible only for debugging samples on DIL format.

20 In accordance with the present invention, an integrated circuit is operable for use with the smart card and operative in both an ISO mode in accordance with the International Standards Organization 7816 (ISO 7816) protocol, and a non-ISO mode in accordance with a
25 non-ISO protocol. This integrated circuit includes a microprocessor and a switching block connected to the microprocessor. An external interface is connected to the switching block and comprises an ISO port operative for communicating in an ISO mode when an ISO mode is
30 detected and a non-ISO mode operative for communicating in a non-ISO mode when a non-ISO mode is detected. The microprocessor and switching block are operative for configuring the ISO port to allow debugging and software development through a serial interface in a

non-ISO mode and allowing debugging and software development through the non-ISO port in an ISO mode.

In one aspect of the present invention, the non-ISO mode comprises a USB mode. A mode
5 configuration circuit is connected to the switching block and configures the integrated circuit in one of the ISO or non-ISO modes. The mode configuration circuit is also operative for detecting a non-ISO mode or ISO mode upon a power-on-reset. The ISO port can
10 comprise a serial interface through which debugging occurs when configured in non-ISO mode. This serial interface can be a I/O contact. A circuit can disable one of the non-ISO port or ISO port used for debugging and software development after debugging and software
15 development is completed.

In yet another aspect of the present invention, a dual-mode smart card includes a dual-mode integrated circuit carried by a card body and includes a first set of contacts forming an ISO port and
20 including serial I/O, clock and reset contacts used in an ISO mode when an ISO mode is detected and a second set of contacts forming a USB port and including D+ and D- contacts used in a USB mode when a USB mode is detected.

25 A mode configuration circuit can be connected to the switching block for configuring the dual-mode integrated circuit in one of the ISO or non-ISO modes and operative for detecting the USB mode and ISO mode upon a power-on-reset. In one aspect of the invention,
30 a reset contact can be switched and deselected and the clock and I/O pins maintained available at a power-on-reset when a USB mode is detected. A latch circuit can latch a mode signal as a control signal for switching and deselecting a reset contact in a USB mode for
35 debugging and/or software development through the ISO

port. A status register can store a mode bit operative for jumping to a USB protocol. A circuit can be used for disabling one of the USB port or ISO port used for debugging and/or software development after debugging
5 and/or software development is completed.

A method of operating a dual-mode integrated circuit for use with the smart card and operative in both an ISO mode in accordance with the International Standards Organization 7816 (ISO 7816) protocol, and a
10 non-ISO mode in accordance with the non-ISO protocol is disclosed. The method comprises the steps of detecting a non-ISO mode or ISO mode of operation and configuring the dual-mode integrated circuit for communicating in ISO or non-ISO mode through a respective ISO or non-ISO
15 port. It also allows debugging and/or software development through a serial interface of the ISO port when a non-ISO mode has been detected and debugging and/or software development through a non-ISO port when an ISO mode has been detected.

20 **Brief Description of the Drawings**

Other objects, features and advantages of the present invention will become apparent from the detailed description of the invention which follows, when considered in light of the accompanying drawings
25 in which:

FIG. 1 is a block diagram of a dual-mode integrated circuit that could be modified for use in accordance with the present invention.

FIG. 2 is a high level flow chart
30 illustrating an example of the ISO/USB hardware detection process that can be used in the present invention.

FIG. 3 is a high level flow chart illustrating an example of the software selection process that can be used in the present invention.

Detailed Description of the Preferred Embodiments

5 The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should
10 not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like
15 elements throughout.

 The present invention advantageously solves prior art problems associated with debugging or developing embedded code. The present invention allows a secondary communication ports for downloading
20 debugging code or extracting variable or registers information that was not possible with current ISO or USB smart cards. Thus, a debugging port is provided for a USB smart card operating in USB mode as user mode and for an ISO/USB smart card operating in ISO mode as
25 user mode. The security of the smart card is guaranteed because the debug port is accessible only for debug samples on DIL format.

 For purposes of background, a dual mode integrated circuit similar to that disclosed in U.S.
30 Patent No. 6,439,464 and modified for use in the present invention and set forth in FIG. 1 for background material. The present invention is not limited to a dual-mode smart card, but can be used on USB only smart cards.

It should be understood that to detect and configure the USB or ISO mode of smart cards as will be explained below, there are several circuits, including a USB/ISO mode detection circuit, a switching block
5 circuit and status and control registers, which could include various delay and latch circuits.

The dual-mode integrated circuit **11** illustrated in FIG. 1 is capable of operating in a first mode such as an ISO mode in accordance with the
10 International Standards Organization 7816 (ISO 7816) protocol, and a second non-ISO mode such as a USB mode in accordance with the Universal Serial Bus (USB) protocol. The dual-mode IC **11** operates selectively in one mode or the other, but not in both modes
15 simultaneously.

The dual-mode IC **11** is situated preferably in the smart card **10** and could be a smart card module as understood by those skilled in the art, and includes a microprocessor **14**, a switching block **16**, and the
20 external interface **12**. The external interface **12** comprises a number of contacts (or pads as used herein), including a voltage supply pad **VCC**, a reference voltage/ground pad **GND**, a first set of pads for the ISO mode, and a second set of pads for the non-
25 ISO mode. The first set of pads preferably includes a reset pad **RST**, a clock pad **CLK** and an input/output **I/O** pad in accordance with the ISO 7816 protocol. The second set of pads preferably includes a D+ pad **DP** and a D- pad **DM** in accordance with the USB protocol. A
30 pull-up resistor **44** and Vterm circuit **46** connect to one of the D+ or D- pads or contacts.

Because the IC **11** operates in one of the two modes which have different external interfaces, the IC will need to determine in which mode to operate. The

IC **11** includes a mode configuration circuit **18** comprising a USB mode detector **34** connected to at least the D- pad.

The USB mode detector may also be connected
5 to the D+ **DP** pad. The mode configuration circuit **18** may also include a USB voltage detector **30** connected to the voltage supply pad **VCC** for detecting a USB mode voltage supply, a latching circuit **40** connected to the switching block and receiving outputs from the USB mode
10 detector **34** and the USB voltage detector **30**, and a control register **42** connected to the latching circuit **40** for storing a mode configuration indicator. There are several possible ways to detect a USB mode. It is possible to detect a logic "1" on the CLK pad. Another
15 is to detect a certain level on pad D+ or D-. These two detections can be used separately, independently or together in serial. Thus, the USB mode detector can also be on a different pad/pin than the D+ or D-, like CLK or RST or some other pad. A status register **41** is
20 operative with the latch **40** and control register **42** and also stores data regarding the mode to operate.

A delay circuit **36** may be connected between the USB mode detector **34** and the latching circuit **40**, while a power-on-reset circuit **32** may be connected
25 between the voltage supply pad **VCC** and the buffer. In one example, the delay circuit **36** delays the detection by the USB mode detector **34** until a predetermined time, e.g. 1-10ms, after first contact to avoid a false detection due to rebound. Also, a logic gate/circuit
30 **38** may be connected between the latching circuit **40** and the detectors **30**, **34**. A 1.5KOhm resistor could be connected between the D- pad **DM** and about 3.6V or VTERM from a voltage regulator to aid in the identification of a low-speed USB device.

In this known example, in a typical dual-mode operation, during the start-up or power-on sequence of the IC **11**, the mode configuration circuit **18** configures the IC **11** to operate in one of the ISO and USB modes while disabling the other mode. For example, the reset pad **RST**, clock pad **CLK** and input/output **I/O** pad are disabled when the IC **11** is configured in the USB mode, and the D+ pad **DP** and D- **DM** pad are disabled when the IC **11** is configured in the ISO mode. To prevent any glitches, the detected mode is latched by the latching circuit **40** while the appropriate bit is set in the control register **42**. Because the mode detection is a hardware detection, the operating system of the IC **11** will then check this bit during the reset routine to access the appropriate code for the latched mode.

Accordingly, if the smart card **10** including the dual mode IC **11** is used with a typical smart card reader, it will operate as specified in the ISO 7816 protocol while the USB interface, i.e. the D+ **DP** and D- **DM** pads, is disabled to consume less power. However, because the IC **11** includes a USB interface, ISO 7816-like transactions can be performed using a low-cost USB device rather than an ISO-compliant smart card reader. Here, the ISO mode interface, i.e. the reset **RST**, clock **CLK** and input/output **I/O** pads, is disabled. Once the IC **11** is configured in one of the modes, it typically stays in that mode until another power-on-reset.

For security and integrity of the dual-mode IC **11**, the mode is detected as soon as possible because once the IC is configured in a mode, it will usually not be changed until another power-on-reset is executed. Further details of a possible implementation

and operation of the described dual-mode IC can be found in the incorporated by reference '464 patent.

The present invention has modified the latching circuit and software in the microprocessor to
5 allow debugging and/or software development. The USB/ISO mode detection circuit **18** detects the USB or the ISO mode at the power-on-reset of the device. Several microarchitectures are possible. For example, in the present invention, it is possible to detect the
10 level of a "logical 1" on the clock pin of the ISO contacts. If the clock is equal to 1, it is the USB mode. If the clock is equal to 0 or is a clock signal, it is the ISO mode.

The switching block (SWB) **16** is configured in
15 one of the two modes depending on the detection. If configured in the ISO mode, the switching block **16** selects and enables the clock, reset, I/O pins, as defined in the ISO 7816 standard, or enables the D+ and D- pins of the USB port if in USB mode. The pins from
20 the disabled port are disabled, i.e., disconnected from the rest of the device. This configuration is accomplished in the hardware and at power-on-reset. To change the mode requires that the device be powered down and powered on. This detection can be stored in a
25 status register **41** to indicate to the embedded application code in which mode it must operate. The control register **42** enables the USB peripheral block to reduce the power consumption to the minimum when ISO mode is chosen.

30 The present invention modifies the hardware and logic of the switching block configuration to use an ISO 7816 or serial I/O pin following the ISO 7816 protocol as a debug and software development port when the USB mode has been detected and selected. It also
35 allows a USB port as a debug and software development

port when the ISO 7816 mode has been detected and selected.

When the mode is detected at power-on-reset, the switching block **16** will only switch the reset pin.

5 The clock and I/O pins will stay enabled and available. This is desirable to reset the device with the correct reset signal in the mode selected. By way of example, in USB mode, it is desirable that the reset comes from the USB peripheral block and not from the reset pin of

10 the ISO port. When detection is done, the mode signal is latched such that whatever happens on the clock pin after the detection period, nothing changes for the mode detected. The mode is the control signal for the switching block **16** to deselect the reset pin.

15 When the USB is reset (generated by the USB peripheral block), it is sent to the CPU and the device starts at its reset vector. When the embedded code determines the mode detected by reading the mode bit in the status register, it jumps to its USB code and

20 enables the USB peripheral block, a USB voltage regulator which could be associated with Vterm **46** and a pull-up resistor to attach the device to the USB bus. This is done by the means of the control register **42**.

The configuration of the device is such that

25 it can normally use its USB port for a USB device application connected to a USB host, usually on a PC, and use its ISO port, including the I/O pin and clock pin to synchronize the data, with the ISO 7816 protocol. This last port can be used for debugging the

30 USB application. It is possible to download in non-volatile on-chip memory any software patches or modules and read or write variables or the values of registers to debug the USB code.

Once the USB application is debugged and

35 ready for production, the ISO port can be disabled by

software or irreversible hardware, such as a fuse, for additional security. This can be reported to the embedded application by a status bit in the status register 41. This status bit can be a non-volatile
5 memory bit such that at the next power-on-reset, it will be impossible to select this debug mode by configuring the switching block in USB mode or in ISO mode only.

In a similar fashion, it is possible to
10 implement a USB debug port for an ISO smart card. At power-on-reset, the detection circuit detects a clock signal on the clock pin and selects the ISO pins for the switching block as it is done normally. At reset, the reset pin rises to 1 and the embedded code reads
15 the mode bit and jumps to the ISO code. At this time, the USB peripheral block is not powered-up and not enabled. By setting to 1 a control bit in the control register, the application can power-up the USB peripheral block. By a second control bit, it enables
20 the USB peripheral block, the same control bit of the USB mode, and attaches the device to the USB bus.

The configuration of the device is such that it can use its ISO port for an ISO smart card application connected to a smart card reader, and use
25 its USB port connected to the PC as a debug port. It allows downloading in the non-volatile, on-chip memory, the software patches or modules, and to read or write variables or the value of register to debug the ISO smart card code. Once the ISO smart card application
30 is debugged and ready for production, the USB port can be disabled by software or irreversible hardware, e.g., a fuse, for additional security. This can be reported to the embedded application by a status bit in the status register. This status bit can be a non-volatile
35 memory bit such that the next power-on-reset will be

possible to select this debug mode by configuring the SWB in ISO mode only.

FIGS. 2 and 3 are flow charts for the mode detection with FIG. 2 directed to the hardware
5 detection and FIG. 3 directed to the software selection.

For the hardware detection shown in FIG. 2, as a non-limiting example, the power-on of the device will enable the device for ISO/non-ISO (NISO) operation
10 at block 100. If the mode is not 1 (block 102), the switching block switches in ISO mode and waits for a reset (RST rise to "1") ATR or Answer to Reset in ISO 7816 protocol (block 104). If the mode is 1, the switching block switches for the device to be in NISO
15 mode (block 106). If the voltage at pad VBus is not greater than 4 volts (block 108), then there is a loopback. If the VBus is greater than 4 volts, then the USB interconnection detection is enabled (block 110). If the CNX USB does not equal 1 (block 112),
20 there is a loopback, but if yes, the USB mode is selected and a USB reset is generated reset (block 114).

As to the software selection shown in FIG. 3, a reset vector is first established at block 200. If
25 the bit read mode does not equal 1 (block 202), the ISO 7816 is selected and it jumps to the ISO software (block 204). If the bit read mode equals 1, the non-ISO is selected and jumped to non-ISO software (block 206), such as the USB software. If the device is
30 already attached (block 208), a USB reset (block 210) is accomplished. If the device is not attached, the device waits a period of time OMS (block 212), and the bit read CNX USB Y times (block 214). If the CNX USB does not equal 1 (block 216), then the device is in an
35 unknown mode and it jumps to mute status (block 218).

If the CNX USB equals 1, the USB mode disables the interconnection detection (CNXDET) (block 220), and the code is jumped to USB software (activate, configure USB block) and the device is attached (block 220).

5 Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the
10 invention is not to be limited to the specific embodiments disclosed, and that the modifications and embodiments are intended to be included within the scope of the dependent claims.